


# Diet quality indices and the risk of type 2 diabetes in the Tehran Lipid and Glucose Study

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## ABSTRACT

**Introduction** The aim of this study was to assess the prospective association between diet quality and risk of type 2 diabetes (T2D).

**Research design and methods** Eligible adults (n=7268) were selected from among participants of the Tehran Lipid and Glucose Study with an average follow-up of 6.6 years. Dietary intakes were assessed using a valid and reliable semiquantitative Food Frequency Questionnaire. Anthropometrics and biochemical variables were evaluated at baseline and follow-up examinations. Dietary pattern scores were calculated for the Healthy Eating Index 2015, Mediterranean diet and the Dietary Approaches to Stop Hypertension diet. Multivariate Cox proportional hazards regression models were used to estimate the development of T2D in relation to diet quality.

**Results** This study was conducted on 3265 men and 4003 women aged 42.4±14.6 and 40.6±13.5 years, respectively. After adjustment for potential confounders, all three diet quality scores were not associated with risk of T2D. Among individual components of the examined dietary patterns, risk of T2D increased from quartiles 1 to 4 for sodium intake (HR (95% CI) 1.00, 0.97 (0.75 to 1.25), 1.17 (0.92 to 1.49), 1.28 (1.01 to 1.62),  $P_{\text{trend}} < 0.01$ ) and decreased from quartiles 1 to 4 for red meat intake (HR (95% CI) 1.00, 0.91 (0.72 to 1.14), 0.75 (0.58 to 0.95), 0.85 (0.67 to 1.08),  $P_{\text{trend}} < 0.01$ ).

**Conclusion** This study emphasizes a potentially protective relationship of moderate red meat intake against development of T2D; also higher intake of sodium is related to risk of T2D.

## INTRODUCTION

Type 2 diabetes (T2D) remains as a serious public health concern worldwide. It has been estimated that nearly 693 million people will suffer from T2D by 2045.<sup>1</sup> Diet quality appears to play an important role in the development of T2D, also identification of the optimal diet for prevention of T2D is a public health priority.<sup>2</sup> Many nutritional investigations concentrate on single nutrients or foods, while the combination of nutrients or foods has cumulative and synergistic effects.<sup>3</sup> Adherence to high-quality diets, especially for individuals at higher risk for T2D, can be an

## WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Previous studies indicated that rare studies investigated the association between common dietary patterns and risk of type 2 diabetes (T2D); limited data are available regarding the generalizability of these relationships.
- ⇒ To date, most studies were conducted in Western countries, with limited information from Asian population.

## WHAT THIS STUDY ADDS

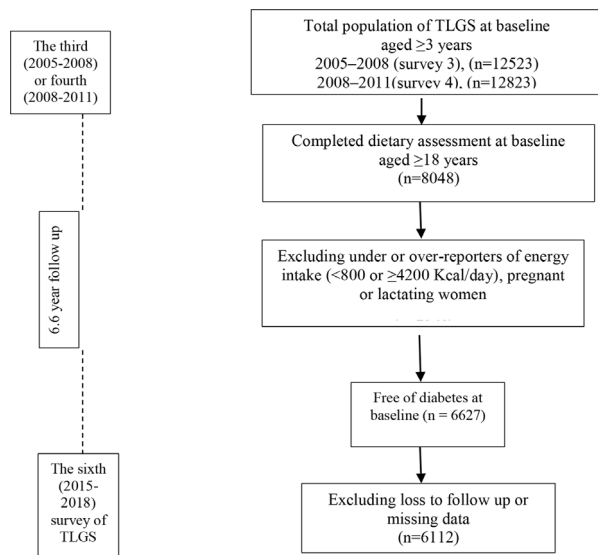
- ⇒ Healthy Eating Index, Mediterranean diet and the Dietary Approaches to Stop Hypertension diet were not associated with risk of T2D.
- ⇒ A high intake of sodium increased the risk of T2D.
- ⇒ A higher red meat intake decreased the risk of T2D, in other words moderate red meat intake decreased the risk of T2D.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ This current study proposed a balanced intake of food is the main feature for the development of dietary indexes; according to cultural differences in dietary habits, the scoring pattern in dietary indexes in each society is different.

approach to help them delay or prevent their onset of disease.

Review of previous studies indicates that the association between common dietary patterns and risk of T2D has been investigated less, and almost only in Western countries<sup>4-9</sup>; limited data are available regarding the generalizability of these relationships. The common dietary patterns in Asian populations may be related to incident T2D,<sup>10 11</sup> who have differing diet cultures and different lifestyle, genetic and metabolic backgrounds from Western population. Given that quantity and quality of Asian diets differ from Western diets, it can be of particular concern to evaluate these common dietary patterns in association with risk of T2D in Asian population.<sup>12</sup> Therefore, we aimed to prospectively



**Figure 1** Outline of study participants' selection. TLGS, Tehran Lipid and Glucose Study.

evaluate the association between three predefined diet quality indices, including the Healthy Eating Index 2015 (HEI-2015), Mediterranean diet (MD) and the Dietary Approaches to Stop Hypertension (DASH) diet in relationship with the incidence of T2D in a group of Tehranian adults.

## METHODS

### Study population

Subjects of this cohort study were selected from participants of the Tehran Lipid and Glucose Study (TLGS), a population-based prospective study performed to determine the risk factors for non-communicable diseases in a sample of residents from District 13 of Tehran, the capital of Iran. The first examination survey was performed from 1999 to 2001 on 15005 individuals aged  $\geq 3$  years using the multistage stratified cluster random sampling technique, and follow-up examinations were conducted every 3 years, 2002–2005 (survey 2), 2005–2008 (survey 3), 2008–2011 (survey 4), 2012–2015 (survey 5), and 2015–2018 (survey 6), to identify recently developed diseases.

Of individuals participating at baseline (surveys 3 and 4), 8048 subjects aged  $\geq 18$  years were randomly selected and completed the dietary assessment. After excluding subjects with under-reporting or over-reporting of energy intake ( $< 800$  or  $\geq 4200$  kcal/day) ( $n=780$ ), a total of 7268 adult men and women with available dietary, biochemical and anthropometric data were selected as the baseline population and followed until survey 6 (participants entering at surveys 3 and 4 were followed respectively three times and two for the outcome measurements). Of these participants, we excluded pregnant or lactating women, and also subjects with prevalent T2D ( $n=597$ ) at baseline. Finally, after excluding participants missing any follow-up data ( $n=515$ ), 6112 subjects remained and entered the analysis (figure 1).

All methods were carried out in accordance with their relevant regulations and guidelines.<sup>13</sup>

### Dietary intake measurements

Dietary assessment was performed by a valid and reliable 168-item semiquantitative Food Frequency Questionnaire; trained dietitians collected data on the consumption of standard serving sizes of a list of foods through face-to-face personal interviews. The intake frequency of each food item during the previous year on a daily, weekly, or monthly basis was converted to daily intakes; portion sizes were then converted to grams using household measures. Since the Iranian food composition table (FCT) is not complete, the US Department of Agriculture FCT was used to analyze foods.<sup>14</sup>

As measures of quality of the overall diet of the participants, three dietary indices were calculated based on the usual intake estimates (table 1). The HEI-2015, the latest iteration of the index, used to represent diet quality and adherence to the healthy eating for chronic disease prevention, and also designed to assess adherence to the 2015–2020 dietary guidelines for Americans.<sup>15</sup> It consists of four moderation components (sodium, added sugars, refined grains, and saturated fats) and nine adequacy components (total vegetables, whole fruits, total fruits, whole grains, total protein foods, greens and beans, seafood and plant proteins, dairy, and the ratio of fatty acids). The scoring of HEI is calculated based on density (amount per 1000 kcal, the ratio of fatty acids) and recommendations are in the range of 1200–2400 kcal dietary intake. To estimate the score of HEI, six items from nine adequacy components (total fruit, whole fruit, total vegetables, greens and beans, total protein foods and seafood and plant proteins) each acquired a score of 0 and 5, respectively, for the lowest and highest consumption. The other three adequacy items (whole grains, dairy and the ratio of fatty acids) were acquired from 0 to 10 for the lowest and highest consumption, respectively. The four moderation items acquired a score of 10 and 0 for the lowest and highest intakes, respectively.

Maximum scores show low intakes of moderation items (a person's consumption is at or below the recommended level) and high intakes of adequacy items (a person's consumption reaches the recommended level). We summed up the scores for all 13 integrals to compute the HEI score. Thus, the total HEI score ranged from 0 (no adherence) to 100 (maximal adherence).

The MD score was defined according to Trichopoulou *et al*,<sup>16</sup> including the following eight components: a higher consumption of vegetables, nuts and fruits, cereals and legume; a high ratio of monounsaturated fatty acid (MUFA) to saturated fatty acid (SFA); a moderately high consumption of fish; a low-to-moderate consumption of dairy products, mostly in the form of yoghurt or cheese; and a low consumption of poultry and meat. Each food component was adjusted for total energy intake (gram per 1000 kcal) to determine the MD score. The cut-off point for each of these eight items was the sex-specific

**Table 1** Healthy Eating Index 2015, Mediterranean diet and DASH component standards for scoring

Component	Maximum points	Criteria for maximum score	Criteria for minimum score of zero
<b>Healthy Eating Index</b>			
<i>Adequacy</i>			
Total fruits	5	≥0.8 c equivalents/1000 kcal	No fruit
Whole fruits	5	≥0.4 c equivalents/1000 kcal	No whole fruit
Total vegetables	5	≥1.1 c equivalents/1000 kcal	No vegetables
Greens and beans	5	≥0.2 c equivalents/1000 kcal	No dark green vegetables or beans and peas
Whole grains	10	≥1.5 oz equivalents/1000 kcal	No whole grains
Dairy	10	≥1.3 c equivalents/1000 kcal	No dairy
Total protein foods	5	≥2.5 oz equivalents/1000 kcal	No protein foods
Seafood and plant proteins	5	≥0.8 c equivalents/1000 kcal	No seafood or plant proteins
Fatty acids	10	(PUFAs+MUFAs)/SFAs ≥2.5	(PUFAs+MUFAs)/SFAs ≤1.2
<i>Moderation</i>			
Refined grains	10	≤1.8 oz equivalents/1000 kcal	≥4.3 oz equivalents/1000 kcal
Sodium	10	≤1.1 g/1000 kcal	≥2.0 g/1000 kcal
Added sugars	10	≤6.5% of energy	≥26% of energy
Saturated fats	10	≤8% of energy	≥16% of energy
<b>Mediterranean diet</b>			
<i>Favorable components</i>			
Vegetables		≥sex-specific median	≤sex-specific median
Nuts and fruits		≥sex-specific median	≤sex-specific median
Cereals		≥sex-specific median	≤sex-specific median
Legume		≥sex-specific median	≤sex-specific median
MUFA/SFA		≥sex-specific median	≤sex-specific median
Fish		≥sex-specific median	≤sex-specific median
<i>Unfavorable components</i>			
Dairy products		≤sex-specific median	≥sex-specific median
Poultry and meat		≤sex-specific median	≥sex-specific median
<b>DASH</b>			
Fruits		Q1=1 point	
Vegetables		Q2=2 points	
Nuts and legumes		Q3=3 points	
Whole grains		Q4=4 points	
Low-fat dairy		Q5=5 points	
Sodium*			<i>Reverse scoring</i>
Red and processed meats*			Q1=5 points
Sweetened beverages*			Q2=4 points
			Q3=3 points
			Q4=2 points
			Q5=1 point
*Higher quintiles represent higher intake; however, in constructing the DASH score, high intake and high quintiles received lower scores. DASH, Dietary Approaches to Stop Hypertension; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; Q, quintile; SFA, saturated fatty acid.			

median intake in the population; a value of 1 was considered as a high intake (at or above the median) of each of the favorable components (vegetables, nuts and fruits, cereals, legume and fish) or to a low intake (below the median) of each of the unfavorable components (dairy

products and meat). In addition, people whose consumption was equal to or higher than the median for unfavorable components and lower than the median for favorable components were considered as a value of 0. For the ratio of daily intake (in grams) of MUFA to SFA,

**Table 2** Baseline characteristics of adult participants of the Tehran Lipid and Glucose Study

	Total sample n=7268	Men n=3265	Women n=4003	P value
Baseline age (years)	41.2±14.1*	42.4±14.6	40.6±13.5	<0.001
Current smokers (%)	22.6	38.2	9.9	<0.001
Physical activity (MET/min/week)	453±793	543±844	379±312	<0.001
BMI (kg/m <sup>2</sup> )	27.1±4.5	26.7±4.0	27.5±5.9	<0.001
Waist circumference (cm)	89.8±13.0	94.5±11.3	85.8±13.4	<0.001
SBP (mm Hg)	113±16.7	117±15.9	109±16.1	<0.001
DBP (mm Hg)	74.3±10.2	77.7±10.3	72.4±10.2	<0.001
Total cholesterol (mg/dL)	219±121	234±138	207±117	<0.001
TG/HDL ratio	3.5±3.0	4.2±3.7	2.9±2.4	<0.001
FBG (mg/dL)	96.1±26.6	97.3±25.5	95.2±26.3	<0.001
2-hour plasma glucose (mg/dL)	104±41	103±43	105±38	0.05
Energy intake (kcal/day)	2287±689	2458±728	2148±609	<0.001
Carbohydrate (% of energy)	58.5±8.3	59.6±6.4	57.5±8.5	<0.001
Protein (% of energy)	14.6±5.2	14.4±2.7	14.6±7.1	0.02
Total fat (% of energy)	30.4±10.3	29.1±6.0	31.8±15.6	0.01
HEI scores	62.3±9.1	61.8±8.8	62.8±9.1	0.09
Mediterranean diet score	4.0±1.3	4.0±1.3	4.0±1.3	0.60
DASH score	24.0±4.9	24.0±4.9	24.0±4.8	0.53
Sodium (mg/day)	3892±4089	3938±2311	3855±5099	0.76
Red meat (serving (30 g)/day)	0.84±0.76	0.91±0.84	0.79±0.69	<0.001

P values derived through Student's t-test and  $\chi^2$  test for quantitative and qualitative variables, respectively.

\*Values are mean±SD unless otherwise listed.

BMI, body mass index; DASH, Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL, high-density lipoprotein; HEI, Healthy Eating Index; MET, metabolic equivalent; SBP, systolic blood pressure; TG, triglyceride.

a value of zero was assigned for intake lower than the sex-specific median and a value of 1 was assigned for intake higher than the median. Alcohol intake is not common in Iranian populations for religious reasons, and alcohol intake cannot be properly estimated in our country due to under-reporting. A total score is computed by summing up the eight item scores, a maximum score of 8; a higher score shows a better dietary quality.

The score of the DASH pattern, as outlined by Fung *et al.*<sup>17</sup> was calculated by summing the scores of eight components: high intake of vegetables, nuts and legumes, fruits, whole grains, and low-fat dairy products and low intake of red and processed meats, sodium, and sweetened beverages. Participants were classified into quintiles based on their intake ranking; individuals in the lowest quintile received 1 point and individuals in the highest quintile received 5 points. Sodium, red and processed meats, and sweetened beverages were reverse coded. Finally, we summed up the eight-item scores to receive an overall DASH score (ranging from 8 for the worst to 40 for the best concordance with the DASH pattern).

### Physical activity

The Persian-translated Modifiable Activity Questionnaire was used to assess the physical activity levels of

participants.<sup>18</sup> Information on the frequency and time of light, moderate, hard, and very hard activities was collected according to the list of common activities of daily life over the past 12 months. Physical activity levels were expressed as the metabolic equivalent hours per week (Met/hour/week).<sup>19</sup>

### Blood pressure and anthropometric measurements

For measuring blood pressure (BP), the participants rested for 15 min while sitting on a chair and a physician measured the BP twice with a minimum interval of 30 s.

Weight was measured to the nearest 100 g using a digital scale (Seca 707), while subjects were barefoot and minimally clothed. Height was measured in a standing position, while the shoulders were in normal alignment, with a minimum measurement of 0.5 cm by a stadiometer. Waist circumference (WC) was measured to the nearest 0.1 cm, over light clothing, at the end of a normal expiration, with an unstretched tape meter at the level of the umbilicus without any pressure to the body surface.<sup>13</sup>

### Laboratory assays

A blood sample was drawn into vacutainer tubes from subjects after 12–14 hours of overnight fasting while they were in sitting position. Blood samples were centrifuged

**Table 3** HRs (95% CI) of diabetes across energy-adjusted quartiles of dietary pattern score in adult participants of the Tehran Lipid and Glucose Study (n=6547)

Variable	Quartiles of score				P <sub>trend</sub> <sup>*</sup>
	Q1	Q2	Q3	Q4	
HEI score					
Median score	52	59	65	72	
Crude	1	1.23 (0.97 to 1.58)	1.20 (0.93 to 1.53)	1.50 (1.18 to 1.90)	<0.01
Model adjusted†	1	1.26 (0.99 to 1.62)	1.07 (0.73 to 1.38)	1.20 (0.94 to 1.53)	0.21
Mediterranean diet score					
Median score	3	4	5	6	
Crude	1	1.07 (0.87 to 1.31)	0.83 (0.40 to 0.84)	1.16 (0.57 to 1.40)	0.17
Model adjusted†	1	1.02 (0.82 to 1.26)	0.89 (0.63 to 1.24)	1.06 (0.87 to 1.30)	0.52
DASH score					
Median score	18	22	26	30	
Crude	1	1.10 (0.85 to 1.41)	1.25 (0.98 to 1.60)	1.70 (1.34 to 2.16)	<0.01
Model adjusted†	1	0.93 (0.72 to 1.20)	0.89 (0.69 to 1.15)	1.13 (0.88 to 1.46)	0.23
Sodium intake					
Median intake (mg/day)	1651	1073	1376	2293	
Crude	1	0.97 (0.75 to 1.25)	1.17 (0.92 to 1.49)	1.28 (1.01 to 1.62)	<0.01
Model adjusted†	1	0.98 (0.76 to 1.26)	1.19 (0.93 to 1.52)	1.31 (1.03 to 1.66)	<0.01
Red meat					
Median intake (serving/day)	0.03	0.12	0.37	0.66	
Crude	1	0.85 (0.69 to 1.08)	0.66 (0.52 to 0.84)	0.69 (0.54 to 0.87)	<0.01
Model adjusted†	1	0.91 (0.72 to 1.14)	0.75 (0.58 to 0.95)	0.85 (0.67 to 1.08)	<0.01

\*Test for trend based on ordinal variable containing median value for each quartile.  
 †Adjusted for age, sex, diabetes risk score, physical activity, smoking, dietary fiber, and total energy intake.  
 DASH, Dietary Approaches to Stop Hypertension; HEI, Healthy Eating Index.

within 30–45 min of collection. All biochemical analyses were performed using a Selectra 2 autoanalyzer at the TLGS research laboratory on the day of blood collection. Fasting blood glucose (FBG) concentration was measured by the enzymatic colorimetric method using the glucose oxidase technique. The standard 2-hour post-challenge blood glucose test was performed using oral administration of 82.5 g glucose monohydrate solution (equivalent to 75 g anhydrous glucose) for all individuals who were not on glucose-lowering drugs.

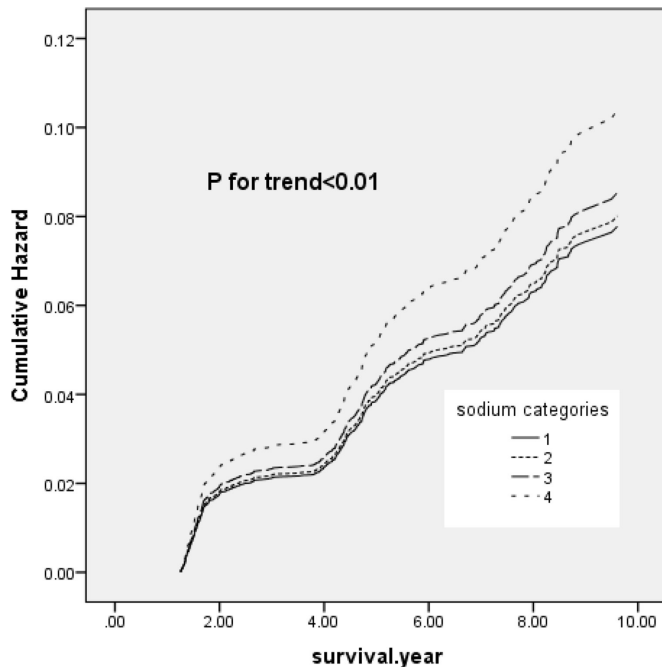
Triglyceride (TG) level was assessed by enzymatic colorimetric tests using glycerol phosphate oxidase and TG kits. High-density lipoprotein cholesterol (HDL-C) concentration was determined after precipitation of the apolipoprotein B-containing lipoproteins with phosphotungstic acid. A lipid standard (Cfas, Boehringer Mannheim; catalog number: 759350) was used to calibrate the Selectra 2 autoanalyzer on each day of the laboratory analysis, and all samples were analyzed only when the internal quality control met the standard criteria. Assay performance was monitored once in every 20 tests using lipid control serum, Percinorm (normal range) and Percipath (pathological range), where applicable (Boehringer Mannheim;

catalog numbers 1446070 for Percinorm and 171778 for Percipath). Interassay and intra-assay coefficients of variations were both 2.2% for serum glucose and 1.6% and 0.6% for TG, respectively.<sup>13</sup>

### Definitions

Incidence of T2D was defined as FBG concentrations  $\geq 126$  mg/dL or 2-hour plasma glucose concentrations  $\geq 200$  mg/dL, or treatment with antidiabetic medications.<sup>20</sup>

The diabetes risk score (DRS) was based on systolic blood pressure (SBP), family history of T2D, TG/HDL-C, FBG, and waist to height ratio; this approach is superior to relying exclusively on the 2-hour plasma glucose alone for identifying individuals at high risk of developing diabetes. DRS was measured as follows: SBP (mm Hg): <120 (0 point), 120–140 (3 points),  $\geq 140$  (7 points); family history of T2D (5 points) (a positive family history of diabetes was determined as having at least one parent or sibling with diabetes); FBG (mmol/L): <5.0 (0 point), 5.0–5.5 (12 points), 5.6–6.9 (33 points); TG/HDL-C: <3.5 (0 point),  $\geq 3.5$  (3 points); waist to height ratio: <0.54 (0 point), 0.54–0.59 (6 points),  $\geq 0.59$  (11 points).<sup>21</sup>



**Figure 2** Multivariable-adjusted cumulative survival curves for the incidence of type 2 diabetes (T2D) according to sodium categories. The multivariable-adjusted model included age, sex, diabetes risk score, physical activity, smoking, dietary fiber, and total energy intake. The associations between the risk of T2D and quartiles of sodium intake were significant.

### Statistical analyses

Statistical analyses were carried out using the Statistical Package for Social Sciences (V.21.0; SPSS). A two-tailed  $p$  value  $< 0.05$  was considered as statistical significance. We used a  $\chi^2$  test and Student's  $t$ -test for qualitative and quantitative variables to compare the results obtained from the male and female subjects. In case of non-normal nutritional and biochemical variables (TG concentration), log-transformed values were used for statistical analysis. The HR and 95% CI of incident T2D were assessed using multivariable Cox proportional hazards regression models. The incidence of T2D during the follow-up period was considered as dichotomous variables (yes/no) in the models. All three diet quality scores and its components were categorized into quartiles, given the first quartile as the reference. The interval between the first and last observation dates was considered as the survival time for censored subjects. The mid-time between the date of the follow-up visit at which the events were diagnosed for the first time and the most recent follow-up visit preceding the diagnosis was calculated as the event date for the incidence of T2D. Study participants were censored due to death, the end of the observation period or loss to follow-up. The median of each quartile was used as a continuous variable to assess the overall trends of HRs across quartiles of all three diet quality scores in the Cox proportional hazards regression models. Schoenfeld's global

test of residuals was used to assess the proportional hazards assumption of multivariate Cox models. The confounders were selected based on literature; also, each confounder was included in the univariable Cox regression model. A two-tailed  $p$  value  $< 0.20$  was used for determining inclusion in the model.<sup>22</sup> The Cox regression models were adjusted for several potential confounders including age, sex, DRS, physical activity (continuous), smoking (never smoked, past smoker, and current smoker), dietary fiber (gram per 1000 kcal), and total energy intake.<sup>23</sup>

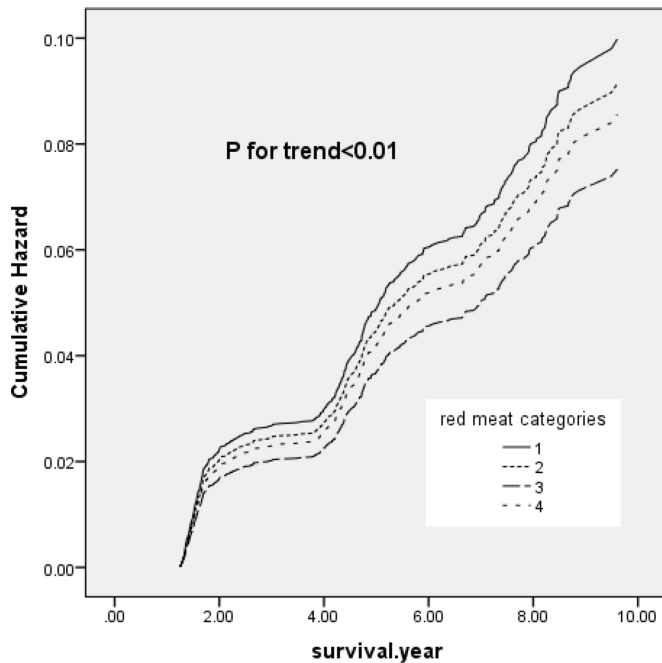
### RESULTS

**Table 2** represents the baseline characteristics of the men and women. The mean age of subjects at baseline was  $42.4 \pm 14.6$  and  $40.6 \pm 13.5$  years in men and women, respectively. Men were older, had worse smoking habits, greater levels of physical activity, lower body mass index and higher WC than women. In addition, men had higher values of SBP, diastolic blood pressure, total cholesterol, TG/HDL ratio, and FBG. Men showed greater amounts of energy and carbohydrate consumption than women. Intakes of total fat, protein and red meat were higher in women compared with men.

After an average follow-up of 6.6 years, new onset of T2D was developed in 549 participants. HRs (95% CI) of T2D for quartiles of the dietary pattern scores and its components are presented in **table 3**. Online supplemental table 1 represents HRs (95% CI) of T2D for each dietary pattern score in men and women separately.

In the crude model, subjects in the upper quartile of HEI and DASH scores and sodium intake had a higher risk of incident T2D than those in the lowest quartile ( $P_{\text{trend}} < 0.01$ ); however, when potential confounders were considered, the statistical significance of crude models disappeared. The associations of the MD scores with T2D risk were not significant in crude or adjusted model.

Furthermore, we investigated the individual components of the dietary patterns: components of the HEI index (sodium, added sugars, refined grains, and saturated fats, total vegetables, whole fruits, total fruits, whole grains, total protein foods, greens and beans, seafood and plant proteins, dairy, and the ratio of fatty acids), MD index (vegetables, nuts and fruits, cereals, legume, ratio of MUFA to SFA, fish, dairy products, poultry, meat), and DASH index (vegetables, nuts and legumes, fruits, whole grains, and low-fat dairy products, red and processed meats, sodium, sweetened beverages). After adjustment for potential confounders, risk of T2D increased from quartiles 1 to 4 for sodium intake (HR (95% CI) 1.00, 0.97 (0.75 to 1.25), 1.17 (0.92 to 1.49), 1.28 (1.01 to 1.62),  $P_{\text{trend}} < 0.01$ ) (**figure 2**) and participants in the fourth quartile for red meat intake had a lower risk of T2D (HR (95% CI) 1.00, 0.91 (0.72 to 1.14), 0.75 (0.58



**Figure 3** Multivariable-adjusted cumulative survival curves for the incidence of T2D according to red meat categories. The multivariable-adjusted model included age, sex, diabetes risk score, physical activity, smoking, dietary fiber, and total energy intake. The associations between the risk of T2D and quartiles of red meat intake were significant.

to 0.95), 0.85 (0.67 to 1.08),  $P_{\text{trend}} < 0.01$  (figure 3). No significant relation was found for other components of the examined dietary patterns (data were not shown).

## DISCUSSION

The current investigation was a prospective cohort study, evaluating the association of multiple dietary patterns and its components with incidence of T2D. All three diet quality scores originally derived in Western populations were not associated with risk of T2D. Among individual components of the examined dietary patterns, participants in the highest quartiles of the sodium intake and lowest quartiles of red meat intake had a statistically significant higher risk of T2D.

We did not observe an association between HEI-2015 score and incident T2D in the present analysis of the study population. In our knowledge, only one study evaluated the association between HEI-2015 and incident T2D; consistent with our result, prospective analysis of the Atherosclerosis Risk in Communities study showed that higher HEI-2015 score was not associated with incident T2D within a community-based population of men and women, black and white from four US communities.<sup>8</sup> In line with our null finding for the HEI-2015, a previous analysis conducted among participants in the multiethnic cohort<sup>11</sup> using the earlier version of HEI demonstrated that HEI-2010 was not associated to T2D risk. However, previous analyses conducted in the Health Professionals

Follow-up Study and the Nurses' Health Study have reported that HEI-2005 is related to diabetes risk.<sup>24</sup> There is no consensus on the antidiabetic attributes of HEI. This inconsistency can be due to the limited evidence regarding the association between HEI and T2D.

In this study population, MD was not related to the risk of T2D incidence. In line with this result, in the Multi-Ethnic Study of Atherosclerosis, no significant association was found between the MD score and risk of incident T2D.<sup>9</sup> This null association is in contrast to previous published result, for example, an analysis of data from European Prospective Investigation into Cancer and Nutrition-Potsdam Cohort demonstrated the MD score had an inverse association with incidence of T2D. Similar results were found in the meta-analyses and systematic reviews<sup>25 26</sup> and also the results of Singapore Chinese Health Study confirmed inverse associations between MD score and risk of T2D.

No association was observed between DASH score and risk of T2D. Jacobs *et al*<sup>11</sup> reported that the associations between DASH score and incident T2D were stronger in whites than in Japanese Americans and Native Hawaiians, although several studies with whites reported null associations.<sup>4 27</sup> In contrast, two meta-analyses of eight<sup>7</sup> and five prospective studies<sup>5</sup> revealed an inverse association with risk of T2D.

There is a remarkable overlap of the MD and DASH components, such as legumes, nuts, fruits, and vegetables as advantageous components (though evidence for their relationship with diabetes risk is limited<sup>28 29</sup>) and red and processed meat as a rather detrimental component (evidence for their relation with diabetes is strong<sup>30</sup>). Findings from the InterAct study suggest that the relation of the MD with diabetes may mostly be related to meat consumption.<sup>31</sup> In our study, higher scores for the MD and DASH index have no associations with T2D, whereas higher quartiles for red meat intake had a strong association with the lower risk of T2D. Most high-quality diets restrict the intake of red meat because of detrimental impact of high intake of red meat.<sup>32</sup> In this study population, total meat intake in the highest quartile was less than two servings/day. According to the Organisation for Economic Co-operation and Development, consumption of meat in Iranian population is significantly low in comparison to other populations in the world.<sup>33</sup> It seems that moderate red meat intake decreased the risk of T2D.

These findings emphasize that the method used to achieve a healthy diet varies, because there are several ways to reach high scores on each index; furthermore, the definition of healthy diet or high-quality diet is different in every population. A balanced intake of food is very important and this can be the main feature for the development of dietary indexes; according to cultural differences in dietary habits, the scoring pattern in dietary indexes in each society is different.<sup>34</sup>

Previous studies appear to indicate that high intake of sodium is related with insulin resistance.<sup>35–37</sup> A high sodium intake could produce insulin resistance by decreasing insulin-stimulated glucose transport in skeletal muscle.<sup>38–39</sup> High-sodium diets may also impair the microvascular response to insulin in skeletal muscle, leading to the insulin resistance state in this tissue. This vascular affection could be the result of enhanced angiotensin II signaling or angiotensin II type 1 receptor levels.<sup>40–41</sup>

The prospective design of the present study allowed the estimation of incident diabetes with less worry about reverse causality between diet quality and outcome. The current study had its limitations too; since assessment of diet was implemented only at baseline, changes in dietary habits were not taken during follow-up. Considering the observational design of the current research, residual confounding (eg, socioeconomic levels) may not be considered. We did not split the analysis by gender due to the low number of cases and power reduction.

Our study suggests that a higher consumption of red meat is negatively associated with T2D, and a high intake of sodium is related to risk of T2D. Furthermore, this study stresses the important role of moderate red meat intake on T2D.

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